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FINAL REPORT

NASA COOPERATIVE AGREEMENT NCC3-383

"PHYSICAL AND CHEMICAL PROPERTIES AND SPACE-ENVIRONMENT STABILITY OF NEW MATERIALS FOR SPACE POWER AND COMMERCIAL APPLICATIONS"

November 26, 1996

PRINCIPAL INVESTIGATOR:

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GRANT PERIOD:

January 1, 1995 - September 30, 1996

I. GOALS AND OBJECTIVES

To test and evaluate suitability of materials for use in space power systems and related space and commercial applications, and to achieve sufficient understanding of the mechanisms by which the materials perform in their intended applications. Materials and proposed applications include but were not limited to: Protective coatings for surfaces exposed to the space environment, electrochromic thermal control materials, atomic-oxygen-durable materials, improved wiring insulation for space power systems, iron-bearing graphite fibers for use in composite EMI shields, arc-proof transparent coatings for photovoltaic arrays, and cooperative research programs with industrial companies.

II. ACCOMPLISHMENTS vs GOALS AND OBJECTIVES

Useful and informative results were obtained on virtually all materials investigated. The results were presented in a total of six technical papers and NASA Technical Memoranda (copies of covers attached).

For example, arc-proof solar array coatings with outstandingly high transparency (greater than 91%) were prepared and their electrical and optical properties tested. Work was started on a promising new method for adjusting the sheet resistivity by doping with air, making these films useful in a wide variety of space and commercial applications The magnetic and electrical properties of

new types of iron-bearing graphite fibers were studied in some detail; they indicate the existence of iron nanoparticles in the fibers. These fibers are under consideration for use in lighweight EMI shielding. We designed experiments on electrochromic coatings that will provide valuable information for improving their switching speed. Preliminary work was done on a quick, low-cost method for testing quality of commercially-produced graphite fibers.

Extensive testing of new candidate coatings for protection of spacecraft in LEO was carried out. One project received an award from NASA for an important study of x-ray embrittlement of FEP Teflon in LEO.

Several collaborations with industry were initiated.

Proposed research on a few materials was terminated early, by agreement between the Technical Monitor and Principal Investigator, when research results or changing NASA needs suggested a shift to higher-priority items. That is consistent with the investigative nature of this research and the intent of the Cooperative Agreement instrument.

III. INTERACTION WITH INDUSTRY

Several of our research projects attracted attention from commercial businesses. In particular, the work on high-resistivity arc-proof coatings has resulted in contacts from approximately seven businesses interested in using these materials for various purposes. Collaboration is being explored with at least one

company at this time.

IV. COSTS

All work was accomplished within budget. There were no cost overruns.

Abstract Submitted

for the Fall 1996 Meeting of the

Ohio Section/American Physical Society

1 - 2 November 1996

Suggest Title of session
in which paper should be placed
Thin Films, or Solid State Physics

Transparent, High-Resistivity ITO-Based Thin Films. A. M. PAL, A. J. ADORJAN, P. D. HAMBOURGER, Cleveland State U.;* JOYCE A. DEVER, NASA Lewis Research Center; and HENRY FU, Ohio Aerospace Institute. Some space and commercial applications demand durable, transparent, conductive thin films with high, tailorable sheet resistivity. We have prepared 30-nm-thick amorphous films by reactive sputtering from a dual ITO (indium tin oxide)/MgF_2 target in the presence of high-purity air. Sheet resistivities of 10^3-10^{11} ohms/square with visible transmittance as high as 92% were obtained in films with 0-17 volume % MgF_2. Post-deposition heating to 250 C in high-purity air increases resistivity by as much as 4 orders of magnitude, reducing carrier concentration to as low as $2x10^{14}$ cm^{-3} (presumably by filling oxygen vacancies). Temperature dependence of the Hall coefficient and resistivity will be discussed.
*Supported by NASA Lewis Research Center, Cooperative Agreements NCC3-383 and NCC3-486.

Prefer Standard Session

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Abstract Submitted for the
39th Annual SVC TechCon
Philadelphia, PA
May 5-10, 1996

Preferred Session: OPTICAL COATING

Very-High-Transmittance ITO-MgF_2 Films with Tailorable Conductivity.* R. FERRANTE[†], ANNA MARIA PAL[†], P. D. HAMBOURGER[†], JOYCE A. DEVER[×], SHARON K. RUTLEDGE[×], ERIC BRUCKNER[†❖], and KAREN MAYER[†]. ---Highly transparent films with tailorable electrical conductivity have been prepared by co-sputtering indium tin oxide (ITO) and MgF_2 in the presence of high-purity air. Films ~ 30 nm thick deposited on 0.75-mm-thick fused silica have visible-wavelength transmittance as high as 92% (not corrected for substrate absorption) - considerably better than that of mass-produced ITO films of similar thickness. Room-temperature sheet resistances (R_s) of ~ 10^5-10^{10} ohms/square were obtained with MgF_2 content of ~ 15-25%. The temperature coefficient of R_s is negative and increases in magnitude with room-temperature R_s. In most samples, the temperature dependence of R_s can be fitted to the 3-dimensional Mott variable range hopping formula with hopping lengths on the order of a few nm. The short hopping length, together with the high optical clarity, suggest that the ITO and MgF_2 are intimately mixed rather than deposited in large granules. Additional electrical, optical, and stability data will be presented and discussed.

*Supported in part by NASA Grants NCC3-339 and NCC3-383
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(FOOTNOTES OMITTED BECAUSE CONFERENCE DOESN'T PRINT THEM IN ABSTRACT BOOKLET. SUPPORT ACKNOWLEDGEMENT WILL BE MADE IN FULL PRINTED VERSION TO BE DISTRIBUTED AT CONFERENCE.)

Abstract Submitted for the 40th SVC TechCon
April 12-17, 1997

Preferred Session - OPTICAL COATING

High-Transparency Thin Films with Tailorable Sheet Resistivity.

A. M. Pal, A. J. Adorjan, and P. D. Hambourger, Cleveland State University; J. A. Dever, NASA Lewis Research Center; Henry Fu, Ohio Aerospace Institute.

We have previously reported on highly transparent films (>92% for thickness of 300 Å) with sheet resistivity (R_s) of 10^5-10^{11} ohms/square prepared by co-sputtering of indium tin oxide (ITO) and MgF_2 (SVC 39th TechCon Proceedings, p. 222). Films with $R_s > 10^6$ ohms/square were rather unstable - R_s increased by as much as 2 orders of magnitude within 8 months after deposition. We have therefore tried to minimize the use of MgF_2 by post-deposition heat treatment (250 C) in high-purity air to reduce the carrier concentration (n) by filling oxygen vacancies. In this way we have obtained pure ITO films with R_s up to $3x10^7$ ohms/square. Preliminary data suggest these films are more stable over time than untreated ITO/MgF_2 samples with similar R_s. Air heat treatment of films containing 5 volume % MgF_2 increases R_s to 10^8-10^9 ohms/square. However, R_s of the latter is sensitive to the ambient atmosphere - probably due to their low n ($3x10^{14}$-$3x10^{15}$ cm^{-3}). A search for a less-reactive alternate to MgF_2 will be described and the conduction mechanism will be discussed using low-temperature Hall and resistivity data.

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